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CIRCULATION DEVICE FOR A ROTARY COMPRESSOR, ROTARY COMPRESSOR, AND METHOD FOR OPERATING THE SAME

The invention relates to a circulating apparatus for a rotary compressor in accordance with the preamble of claim 1. The invention further relates to a rotary compressor in accordance with the preamble of claim 5. The invention further relates to a method for the operation of a rotary compressor in accordance with the preamble of claim 9.

Rotary compressors such as turbo compressors, gas turbines, steam turbines or gas compressors are known for the compressing of gases, in particular of hydrocarbons such as natural gas, which use contact-free dry gas seals to seal the gap which results between the housing and the rotating shaft.

These seals are arranged along the rotating shaft and separate the process chamber arranged inside the machine housing and standing under pressure from the environmental pressure. The sealing apparatus is typically arranged in a sealing chamber separate from the process chamber and is preferably designed as a labyrinth seal. A sealing gas is supplied to the sealing chamber in order to make available the gas required for the sealing. A gas from an external source, such as for example nitrogen, or also the process gas which is compressed by the rotary compressor, is suitable as a sealing gas. Corresponding feeds and passages are provided in order to supply the sealing gas via a sealing gas supply system to the sealing chamber.

A disadvantage of such contact-free dry gas seals is the fact that these are frequently damaged.

It is thus the object of the present invention to propose an arrangement and also a method which permit rotary compressors to be operated more advantageously, at more favourable cost, and more reliably.

This object is satisfied with the circulating apparatus having the features of claim 1. The subordinate claims 2 to 5 relate to further advantageous embodiments. The object is further satisfied with a compressor having the features of claim 6. The subordinate claims 7 to 8 relate to further advantageously designed compressors. The object is further satisfied with a method having the features of claim 9. The subordinate claims 10 to 13 relate to further advantageous method steps.

The object is in particular satisfied with a circulating apparatus for the transporting of sealing gas into the sealing chamber of dry gas seals of a rotary compressor including a line which forms a fluid path in order to connect the apparatus to a sealing circuit, including a sealing gas compressor and also a heating device which are fluid-conductingly connected to the line and also including a control apparatus which controls the sealing gas compressor and also the heating device. Process gas such as natural gas is preferably used as the sealing gas.

An advantage of the circulating apparatus in accordance with the invention is to be seen in the fact that the sealing gas is supplied to the sealing chamber heated in such a way that the sealing gas, as a result of the position of the dew point, does not precipitate liquids or solid materials such as hydrates in the dry gas seal. The sealing gas is partially relaxed via the dry gas seal so that the sealing gas cools down as a result of the Joule-

Thomson effect. The apparatus in accordance with the invention or the method in accordance with the invention ensure that no liquids or solid materials precipitate in the dry gas seal. This ensures that only gaseous materials are present in the dry gas seal which guarantees a reliable and long-term operation of the dry gas seal without it being damaged even during longer stoppage of the compressor.

The process gas is preferably used as the sealing gas, however, another gas can also be used for sealing.

The object is further satisfied in particular with a method for the switching off of a rotary compressor having dry gas seals in which the dry gas seals are supplied with a heated sealing gas or process gas during stoppage.

This method is then in particular of advantage when the rotary compressor is switched off and stopped without the process gas being discharged during the stoppage so that the pressure in the rotary compressor is essentially maintained. The pressure in the rotary compressor amounts, depending on the application, for example to between 10 and 500 bar. When a rotary compressor is switched off and the process gas is not discharged, then a pressure equalization of the process gas occurs in the rotary compressor, with the pressure of this pressure equalization being higher than the suction pressure of the compressor. After the stoppage of the compressor, the process gas cools down with time to environmental temperature, with the pressure of the process gas being essentially maintained. If the dew point of the process gas is higher than the environmental temperature, then the danger exists that liquid and perhaps even solid materials such as hydrates precipitate out, in particular in the dry gas seal. The danger exists that these precipitations can damage the dry gas seals, in particular when the compressor is taken into operation again. The

method of the invention now has the advantage that the dry gas seals are supplied with heated sealing gas or process gas in such a way that the precipitation of liquid or solid materials is prevented.

In an advantageous embodiment a phase diagram of the process gas that is used is stored and the process gas is heated on the basis of the phase diagram and of measured values such as temperature and/or pressure of the process gas in such a way that no liquid or solid components precipitate out in the dry gas seal. The phase diagram is dependent on the respectively used sealing gas or process gas. Depending on the respective process gas pumped by the compressor, for example the specific composition of the pumped natural gas, a phase diagram is used which is matched in accordance with the composition. In a preferred embodiment, hydrocarbons (CnHm) are pumped, for example methane, ethane, butane, ... hectane, octane, with the apparatus in accordance with the invention or the method in accordance with invention also being suitable for the pumping of other gases. The use of the process gas hydrocarbons as a sealing gas is in particular therefore demanding because this sealing gas can already precipitate liquids or solid materials at temperatures between 20 and 50°C.

An advantage of the method of the invention is to be seen in the fact that a compressor can be stopped for a longer period of time, for example also for a couple of days, while essentially retaining the operating pressure, without the danger existing that the dry gas seals are damaged. The method of the invention thus enables a compressor to be reliably and cost-favourably switched off and started up again.

A further advantage is to be seen in the fact that the compressor can be kept under pressure over a longer period of time during a stoppage. Thus

it is no longer necessary to discharge the process gas during the stoppage, which can in particular be problematic when the process gas has components which damage the environment, such as for example applies to natural gas.

The invention will now be described in detail with reference to an embodiment. There are shown:

Figure 1 a schematic detail view of a compressor with a circulating apparatus;

Figure 2 a two-phase diagram of the process gas;

Figure 3 a schematic view of a further arrangement of the circulating apparatus in a compressor.

Figure 1 schematically shows an embodiment of a circulating apparatus 1 which is fluid-conductingly connected to a compressor 2. The circulating apparatus 1 includes two process gas lines 1a, 1b between which the gas compressor 1c, also termed a booster, a heating device 1e and also a non-return flap 1f is arranged in order to suck in the sealing gas or process gas via the process gas line 1a, to compress and to heat it with a gas compressor 1c and the heater and to subsequently supply the sealing gas via the process gas line 1b to the compressor 2. In an advantageous embodiment the gas compressor 1c brings about a pressure increase of the sealing gas or process gas by 1 to 2 bar in order to enable a circulatory flow of the gas. The heating device 1e can be designed in different manner and can for example also be arranged inside the process gas line 1a, 1b. The gas compressor 1 could also include a pressure accumulator which is

fluid-conductingly connected to the process line 1a, 1b and serves to damp pulsating oscillations generated by the compressor 1c.

The gas compressor 1c is connected to a drive 1d. The arrangement 1c, 1d can be designed as a piston compressor with two cylinders, with one cylinder serving as a drive element and the other cylinder serving as a compressor element, with the drive element being supplied with compressed air for the driving of the cylinder.

The circulating apparatus 1 can be designed as a separate unit, for example in that all necessary components are arranged in a rack in order, for example, to retro-equip an existing compressor 2. The circulating apparatus 1 can, however, also form part of the compressor 2.

The circulating apparatus 1 can additionally include a filter 1i which is arranged in the fluid path in order to clean the gas of solid materials and/or liquids. The circulating apparatus 1 can moreover include a temperature sensor 1h and/or a pressure sensor 1g. These components 1i, 1g, 1h can be arranged in the circulating apparatus 1 itself or, as shown in the embodiment in accordance with Fig. 1, be arranged with components of the compressor 2, in particular along the sealing gas circuit. The temperature sensor 1h is arranged in Fig. 1 in such a way that it measures the temperature of the sealing gas in the region of the dry gas seal. The temperature sensor 1h could, for example, also be arranged at the process gas line 2m, 2n or 2o in order to measure the temperature of the sealing gas at this position.

An electronic control apparatus 4 serves for the control of the circulating apparatus 1, with this control apparatus 4 being able to form a part of the

circulating apparatus 1 or a part of the compressor 2, or can also be designed as a separate additional component.

The electronic control apparatus 4 is connected via signal lines 4a to the respectively controllable components 1d, 1e, 1g, 1h.

The rotary compressor 2 is designed in a manner known per se and includes a compressor housing 2a and also a shaft 2c which is rotatably journalled with the aid of bearings 2d. Non-illustrated compressor wheels are fixedly connected to the shaft 2c and form, in the interior of the compressor housing 2a, together with further components, the compression spaces which are fluid-conductingly connected to the suction side 2e and to the pressure side 2h.

Gas seals 2b are arranged along the shaft 2c so that sealing chambers form between them. The gas seals 2b are designed as contact-free gas seals, preferably as labyrinth seals. The one sealing chambers are supplied with process gas via process gas lines 2m, 2o, whereas the further sealing chambers are supplied with a sealing gas or buffer gas via feeds 3a, 3c, for example with nitrogen. This sealing gas is for example fed via a discharge line 3b to a flare or via a line 3d to the atmosphere.

The compressor 2 includes a first sealing or process gas circuit 2l, 2m, 2n, 2o along which the process gas circulates during the operation of the compressor 2. The process gas is extracted from the compressor housing 2a with the aid of the process gas line 2l at a pressure slightly above the suction pressure, is thereafter supplied to the filter 2k which holds back solid or liquid components and is then supplied via the process gas lines 2m, 2n, 2o to the illustrated sealing chamber. The circulating apparatus 1 in accordance with the invention forms a second sealing gas circuit in that

the process gas is extracted with the aid of the process gas line 1a from the suction side 2e and is supplied to the compressor 1c. The process gas line 1b opens into the filter 2k. Two non-return flaps 1f, 2p are provided which act passively in such a way that, in dependence in the respective pressure conditions, either a first sealing gas circuit 2l, 2m, 2n, 2o, or a second sealing gas circuit 1a, 1b, 2m, 2n, 2o forms.

During the normal operation of the compressor 2, the first sealing gas circuit is open and the second sealing gas circuit is closed so that the sealing space and the dry gas seals 2b are continually supplied with gas via the lines 2n, 2o.

On switching off or during stoppage of the rotary compressor 2 the compressor 1 is switched on which has the consequence that the non-return flaps 1f, 2p are automatically moved in such a way that the second sealing gas circuit is opened and the first sealing gas circuit is closed. During stoppage the rotary compressor 2 is preferably not vented which has the consequence that the pressure of the process gas equalizes within the housing 2s and the pressure comes to lies substantially above the suction pressure. For a longer stoppage of the rotary compressor 2 the process gas cools down, whereby the pressure of the process gas is essentially preserved or only sinks fractionally as a result of the good sealing action of the dry gas seals. In this state the danger exists that the process gas flowing in very small proportions through the dry gas seals precipitates liquids or even solid materials which remain in the dry gas seals and can in particular damage or even destroy these during running up of the compressor 2. In order to prevent this effect, the first sealing circuit is closed during stoppage of the compressor 2, the second sealing circuit is opened and the process gas is slightly compressed in the compressor 1c and subsequently heated in order to reliably supply the dry gas seals with heated process

gas and in order to thereby prevent a precipitation of liquids or solid substances in the dry gas seal.

Instead of process gas, another available sealing gas could also be used which is heated and circulated in order to protect the dry gas seals from precipitations. For this purpose, the lines 2n, 2o in the embodiment shown in Fig. 1 must be connected to the line 3a and/or 3c and the line 1a to the line 3b or 3d.

In a further advantageous method the pressure and/or the temperature of the sealing gas or process gas can be measured with correspondingly disposed sensors 1h, 1g and the sealing gas or process gas can be pumped or heated in dependence on the measured temperature and/or pressure by the circulating apparatus 1.

Fig. 2 shows a two-phase diagram 5 of the process gas as a function of temperature T and pressure P. The lines 5a, 5c form the boundary between a clearly gaseous or liquid state of the process gas. Inside the line 5a there is the transition phase within which the process gas can have liquid or indeed solid components. The line 5b represents the line where solid materials forms, i.e. where hydrate forms.

An important aspect of the method of the invention is to be seen in the fact that the process gas or sealing gas is heated in such a way that it never reaches the state bounded by the line 5a within which liquids and solid materials precipitate.

In an advantageous method, the associated individual two-phase diagram is determined for each specific process gas or sealing gas and is stored in a memory 4b of the control apparatus 4.

Figure 2 shows at point 6, by way of example, the pressure and temperature value of the process gas within the compressor 2 at a specific time during the stoppage. Through the continuous cooling down of the process gas, the point 6 migrates at an approximately constant pressure along the line 6a of the two-phase diagram 5. With the aid of the two-phase diagram 5 stored in the control apparatus 4, and also with the aid of the temperature of the process gas measured by the sensor 1h, the process gas can be pumped and heated with the aid of a heater 1e so that the point 6 remains outside of the line 5a, in particular I the region of the dry gas seal, so that it is ensured that no liquid precipitation or solid material precipitation occurs in the dry gas seals.

The compressor shown in Fig. 1 only represents an example. The circulating apparatus 1 in accordance with the invention or the method in accordance with the invention can be used with a multitude of different compressors, such as turbo compressors, gas turbines, steam turbines or gas compressors and also different process gases and/or sealing gases.

Fig. 3 schematically shows a further arrangement of the circulating apparatus 1 in connection with a compressor 2. The first sealing gas circuit includes the process gas lines 2l, 2m, 2n, 2o and also the filter 2k. The second sealing gas circuit includes the process gas lines 2l, 1a, 1b, 2n, 2o. The process gas line 2l extracts the process gas from the compressor 2a at an intermediate stage. The circulating apparatus 1 is provided as a bypass to the process gas line 2m, and in Fig. 3 the required valves for the redirection of the liquid flow either through the line 2m or through the circulating apparatus 1 with the lines 1a, 1b are not shown. The circulating apparatus 1 likewise includes the electronic control apparatus 4 and also signal lines 4a, which are not shown. The process gas line 2l could also take the process gas from the compressor 2a at the pressure side 2h.